Implications of Hawking's recent work for black hole jumping astronauts

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Two years ago, in Dublin, Stephen Hawking announced that he had solved the black hole information problem. In essence, he treated a black hole as a particle scattering experiment, as viewed from a long distance away. Particles go in, some sort of stuff goes on, particles eventually come out, instruments detect them.

I want to consider the implications of this, and his conclusions, for a particular experimental situation, in which we create a large black hole of >1000 solar masses by moving a quantity of stars into a region of empty space, waiting until a static black hole (or something like it) is formed, and dropping in an astronaut. Then we wait until the black hole evaporates. We can expect that once the initial excitement is over, we will have a stable object that radiates black body radiation at a very low temperature over an extremely long period until it finally evaporates, and the region is left, presumably, empty.

[Of course there are difficulties − for example, the black hole will in practice keep growing due to starlight until the stars are gone, since it will be colder than starlight, even intergalactic starlight. But these are probably not major issues in principle. I will ignore them for now.]

I will try to avoid speculation completely, and just describe my understanding of the situation. If I am making any errors of logic or interpretation, I hope they will be pointed out. So...

On the basis of quantum theory, the wave function of what finally results from the experiment is given by the sum over every possible history for the particles going in. In the context of quantum gravity, this means summing over every possible history of the particles going in, for every possible topology of spacetime in the region. Hawking (assuming he is right) showed that the non−trivial topologies − i.e. topologies in which black holes actually form − contribute nothing to the final sum of histories.

We could think of all the measurements of what results from this scattering experiment being made at once in some distant future after the black hole is evaporated. When sufficient measurements are made, a particular history (in the more normal sense) of what happened to all the stuff going into and out of the region of space will be determined. This will in principle include a history of what happened to the astronaut and subsequently to the stuff he was made of. The more measurements we make, the closer we come to a unique classical history of events − i.e. a history where the intrinsic uncertainty about what actually happened applies only to small−scale events that do not interest us. Let's assume we make enough measurements to generate such a unique classical history for the astronaut and the stuff he is made of. What is this history like?

We know that it must obey the same boundary conditions as the particle histories that contribute to Hawking's total sum of histories. Therefore, it must be the history of an astronaut who never discovers a spacetime of non−trivial topology; an astronaut for whom the black hole never forms.

So after the experiment is done and the measurements analysed, the question of "what happens to an astronaut jumping into a large black hole" will (if Hawking is right) have an experimentally verified answer. Furthermore, if Hawking is right, this answer will be: he never reaches the event horizon. In other words, physicists (if they do this experiment and Hawking is found to be correct) will have demonstrated that general relativity breaks down somewhere outside the event horizon of a black hole.

Conclusion: IF Hawking's analysis is correct, and IF quantum mechanics is not drastically different from how we imagine it, then whatever form the correct theory of quantum gravity takes, it will involve general relativity breaking down close to the event horizon of a black hole.

Is there a flaw in this analysis, or is it something generally agreed?

− Gerry Quinn

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